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Preparing for the Worst: Attention Is Enhanced Prior to Any Upcoming Emotional or Neutral Stimulus

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Abstract

Do people allocate more or fewer attentional resources when preparing for negative emotional visual stimuli to appear? In three experiments (total $N = 150$), participants performed a change-detection task while expecting a neutral, threatening, disgusting, or joyful stimulus or no stimulus to appear at a fixed moment. Responses to an infrequent dot probe were faster when participants were expecting a distracting stimulus. Importantly, although only negative stimuli impaired change-detection performance, there was no difference between the preparation effect for threatening and neutral stimuli (Experiment 1) or disgusting and joyful stimuli (Experiment 3). The preparation effects were also unaffected by the participant's anxiety level. Experiment 2 confirmed that the threatening images affected performance when the dot probe appeared after the image. These results suggest that the visual system increases alertness in response to any upcoming stimulus and further imply that the effects of emotional stimuli largely occur after, but not before, the stimuli appear.

Keywords

selective attention, distractor inhibition, threat, disgust, preparation effect

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We are constantly surrounded by myriad stimuli that require our attention. Given the endless need to selectively attend to only the most relevant information and to filter out irrelevant stimuli, it is important to ask how one prepares for a distraction when it is surely coming. Surprisingly, however, this question has been largely overlooked, as most selective-attention studies have focused on people's ability to filter out or suppress irrelevant information only after its appearance (Gaspelin & Luck, 2018; Geng, Won, & Carlisle, 2019). A few studies that tested how people prepare to process distracting information before it appears have shown that people do not inhibit distractors before their appearance but rather allocate more attention to the location of the upcoming distractor (Lahav, Makovski, & Tsal, 2012; Tsal & Makovski, 2006). This phenomenon, known as the *attentional white-bear* effect, was later generalized to feature-based attention (Moher & Egeth, 2012), and the same general principle of enhanced attention in the face of distraction was also found in the attention-alertness system.

Other researchers have claimed that people can proactively learn to suppress locations where distractors should be expected (e.g., Wang, van Driel, Ort, & Theeuwes, 2019), contrary to the white-bear notion. However, in these studies, the distractors typically appear together with targets, so shifting attention away from the distractor location also facilitates target detection. By contrast, Makovski (2019) has recently shown that people prepare for the onset of distractors, even in the absence of targets, by allocating more, rather than fewer, attentional resources. This effect is not spatially or temporally specific, which suggests that people are generally more alert when expecting distractors. Notably, this idea of enhanced alertness does not necessarily contradict the notion of distractor suppression,

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as increasing attentional resources before the stimulus may facilitate its suppression afterward.

Furthermore, there is no apparent benefit in turning attention off beforehand, particularly because we are highly trained and efficient in filtering out irrelevant stimuli after their appearance. Moreover, throughout our lifetimes as well as our evolution, there are few cases in which we can be confident that an upcoming stimulus is totally irrelevant and should be ignored in advance. Given the risks of missing a dangerous stimulus, increasing attention at those moments when distraction is expected seems a more adequate behavior than shutting attention down.

Is the preparation effect versatile, or does it treat all upcoming stimuli in the same way? Makovski (2019) has shown that people were faster to respond to an unexpected, infrequent dot probe when it appeared while they were expecting an interfering display than when no stimulus was expected. A similar finding was obtained when observers were expecting task-relevant stimuli, suggesting that preparing for a distracting stimulus is not qualitatively different than preparing for an informative stimulus. Yet it is not clear whether people pay more attention to upcoming distracting stimuli because they specifically anticipate a confusing situation (Flombaum, Scholl, & Pylyshyn, 2008) or because they prepare for all upcoming stimuli, as suggested by the notion of a mandatory process-all mechanism (Tsal & Makovski, 2006). A variety of stimuli need to be tested in order to address this issue and to generalize the implications of the preparation effect.

Additionally, one might argue that the distracting stimuli in the study by Makovski (2019; irrelevant colors during color-memory tasks) bear no real cost for participants. That is, the relatively small cost in the performance of an artificial task might not be sufficient to drive observers to make the effort involved in an in-advance inhibition. By contrast, presenting negative-valence images might pose a more inherent threat that participants would wish to avoid (or attend). Therefore, incorporating threatening images into the preparation paradigm enables us to test whether the visual system prepares differently for these stimuli.

Testing how people prepare for threatening stimuli not only is important for understanding the preparation effect but also is central for the study of the interactions between emotion and cognition. There is ample evidence that negative stimuli bias the allocation of attention in healthy populations and especially in anxious populations (e.g., Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Chajut, Schupak, & Algom, 2010; Makovski, Michael, & Chajut, 2020; Yiend, 2010). Notably, however, most of these studies have focused on how people attend to emotional stimuli after their appearance (for reviews, see Carretié, 2014; Pergamin-Hight, Naim, Bakermans-Kranenburg, van IJzendoorn, & Bar-Haim, 2015); the question of how people prepare for a threat prior to its appearance has been largely ignored. Given the crucial role that researchers attribute to attention biases toward valence stimuli, examining the mechanism of attention preparation is key to the study of emotion and cognition. Because threat-related attention biases are found to be more prominent in anxious participants (Aue, Okon-Singer, 2015; Cisler & Koster, 2010; Mathews & MacLeod, 2002), it is also important to compare how low- and high-anxiety participants prepare for the appearance of threatening stimuli.

Statement of Relevance

Psychologists have long known that emotional images bias people's attention toward them. Yet these effects have been typically tested after the emotional images were presented. This study tested how people prepare for emotional stimuli before the stimuli appear. Recent research found that people are more alert when they know that a stimulus is about to appear, even if they are expecting a distracting stimulus. Because people usually wish to avoid negative emotional images, one might expect that they would prepare differently for such stimuli. Surprisingly, however, we found that people prepare for all images—neutral, joyful, threatening, or even disgusting—in the same way. Furthermore, although anxiety was related to the effect of emotional stimuli after those stimuli were presented, it was unrelated to the preparation effect. These findings suggest that knowing that any stimulus is about to appear increases alertness and that the emotional image's power to bias attention occurs after, but not before, its appearance.

Experiment 1

The goal of this experiment was to test how people prepare for the presentation of a threatening image and whether this effect is modulated by anxiety. To that end, we followed Makovski's (2019) paradigm, which uses an infrequent dot-probe task to probe attention during a change-detection task. That is, the main task of the observers was a simple color-memory task. In one block of trials, an irrelevant neutral-valence image was presented during the retention interval, whereas in a different block of trials, threatening images were presented during the retention interval. These conditions were compared with a block of trials in which no image was presented. To probe attention unpredictably, we presented a dot probe in one quarter of the trials at the moment of the expected distraction, and participants were asked to detect it as fast as they could.

If observers are preparing to suppress a surely distracting threatening image, and they can easily learn exactly when that image is coming (Thomaschke, Bogon, & Dreisbach, 2018), then we should find slower responses to the dot probe in the threat block compared with the no-image and neutral-image blocks. Conversely, it is also possible that observers prioritize emotional stimuli and actually prepare more for their presentation (Koster, Crombez, Verschuere, Van Damme, & Wiersema, 2006). If so, dot-probe detection should be faster in the threat block compared with the neutral block. Finally, if observers are preparing for all upcoming stimuli in the same way, then there should be no difference in their response to the dot probe between the threat and neutral blocks, and responses in both should be faster than in the no-image block.

Prior to the experiment, we measured participants' anxiety levels to test whether preparing for a threatening stimulus is modulated by anxiety.

Method

Participants. All participants completed the experiment for payment (40 New Israeli shekels [NIS], or ~US$12) and were given a monetary bonus of up to 20 NIS (~US$6), depending on their performance in the main (change-detection) task. The participants were 18 to 35 years old, had normal or corrected-to-normal visual acuity, had normal color vision, and reported having no attentional, psychiatric, or neurological disorders.[1]

We aimed to get data from approximately 54 participants, a sample size that has a power of more than 95% to detect an effect size (Cohen's *f*) of .25 of a within-between interaction in a repeated measures analysis of variance (ANOVA) with three measurements and two groups (G*Power 3.1; Faul, Erdfelder, Buchner, & Lang, 2009). To compensate for possible exclusions, we tested 61 participants (19 males, mean age = 24.9 years).

All participants completed an informed consent form. They were told that some of the images might make them uncomfortable and that they would be allowed to stop the experiment with no penalty. The study was approved by the ethics committee of the Psychology and Education department at the Open University of Israel.

Equipment and stimuli. Participants sat approximately 55 cm away from a 23.5-in. monitor (resolution = 1,920 × 1,080 pixels; refresh rate = 60 Hz) in a dimly lit room. The experiment was programmed using the Psychophysics Toolbox (Brainard, 1997) and implemented in MATLAB (The MathWorks, Natick, MA). The memory items were filled colored circles (radius = 0.98°) sampled randomly without replacement from nine unique colors (orange, red, green, blue, white, yellow, purple, brown, and azure). The memory items were placed equidistantly on an imaginary circle (radius = 4.2°) in the center of the screen. The memory-set size was four for 28 participants and three for 33 participants. This difference did not interact with any of our main findings, so we collapsed all the data together.

The threat and neutral distractor displays consisted of an image (11.2° × 11.2°) placed at the center of the screen. Thirty neutral images and 30 threatening images were selected from the International Affective Picture System (IAPS; Lang, Öhman, & Vaitl, 1988), according to normative ratings for valence and arousal with a range of 1 to 9. The threat images were rated as significantly less pleasant than the neutral ones ($M = 2.30$ vs. $M = 5.13$), $t(58) = 35.68$, $p < .001$, Cohen's $d = 9.21$, and their arousal rating was higher ($M = 5.83$ vs. $M = 3.44$), $t(58) = 13.31$, $p < .001$, Cohen's $d = 3.44$.

Prior to the beginning of the experiment, participants completed an online Hebrew version of the common State-Trait Anxiety Inventory (STAI). The questionnaire includes 20 state and 20 trait statements, and participants rate how well each statement describes them on a scale of 1 to 4. Consequently, the range of each inventory is 20 to 80 (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983).

Procedure. Each trial began with a small white fixation cross (0.17° × 0.17°) presented against a black background for 800 ms. The cross remained on the screen throughout the trial except during the distracting display. The memory array was displayed for 250 ms, followed by a 700-ms blank retention interval. Then, in the neutral and the threat trials, an irrelevant image was presented for 250 ms. The participants were told that the distractor display was irrelevant to their task and that they could ignore it. In the no-image condition, the fixation cross disappeared for 250 ms with no interfering display, in order to match the temporal structure of the retention interval. After a random interval of 300, 400, 500, 600, 700, or 800 ms, the test probe was displayed randomly at one of the memory locations. Randomly, in half of the trials, the test color was identical to the color presented at that location before, whereas in the other half of the trials, an old color was presented at a different location (Figs. 1a–1c). Participants were asked to indicate as accurately as possible whether the color was in its old location (by pressing the "h" key) or not (by pressing the "j" key). A yellow smiley face (radius = 0.98°) was presented for 250 ms after a correct response; a sad face was presented for 600 ms after an error. The intertrial interval was 200

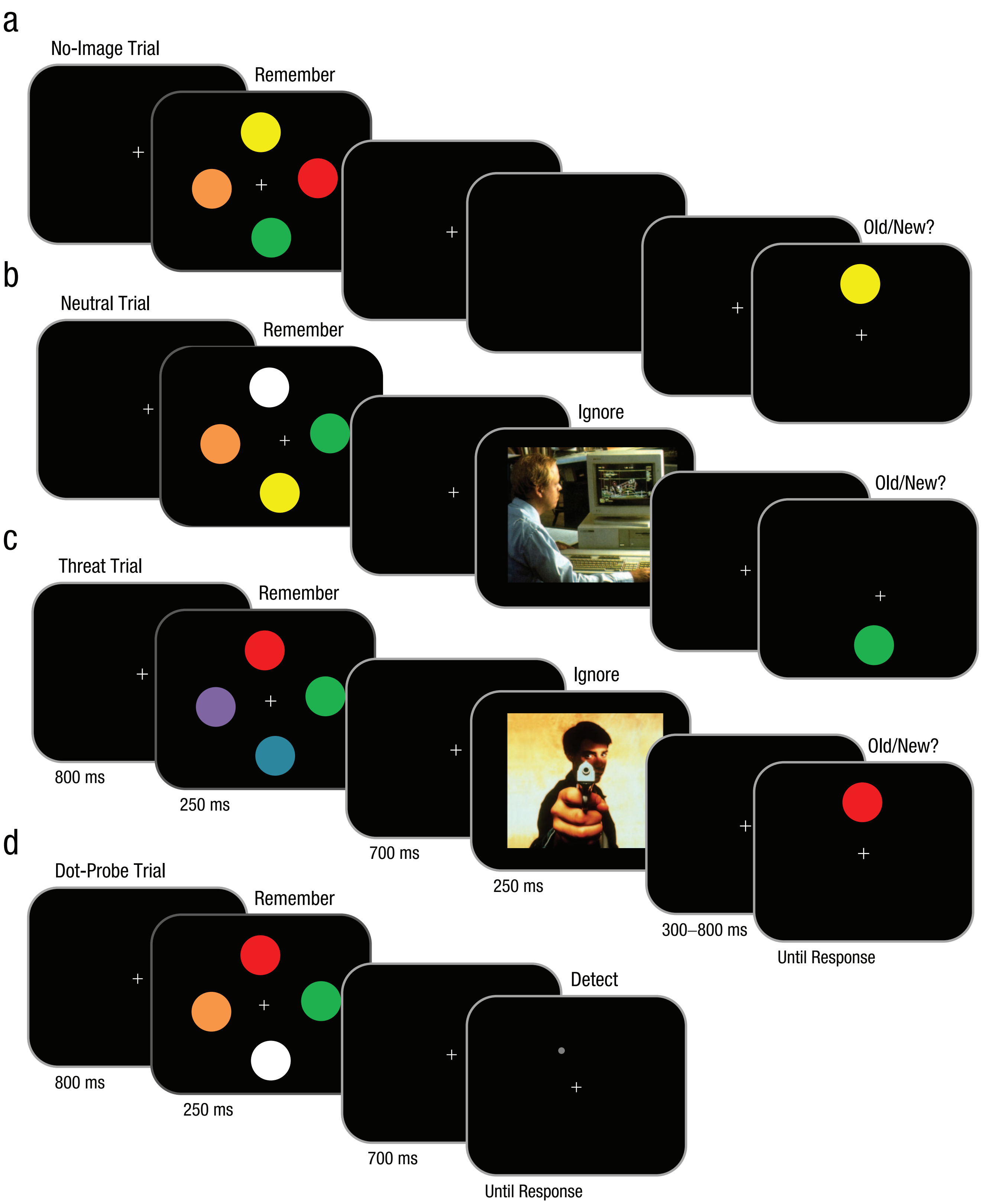

Fig. 1. Example memory trials in the (a) no-image, (b) neutral, and (c) threat blocks, as well as (d) dot-probe trials. In all trials, participants were shown a memory array of four differently colored circles. In neutral and threat trials, this was followed by a neutral or threatening image, respectively, which participants were instructed beforehand to ignore. Participants then identified whether a color probe was in the same location as it was in the memory array. Additionally, in 25% of the trials in each block, we probed attention at the time of the expected distractor by presenting an unpredictable dot probe.

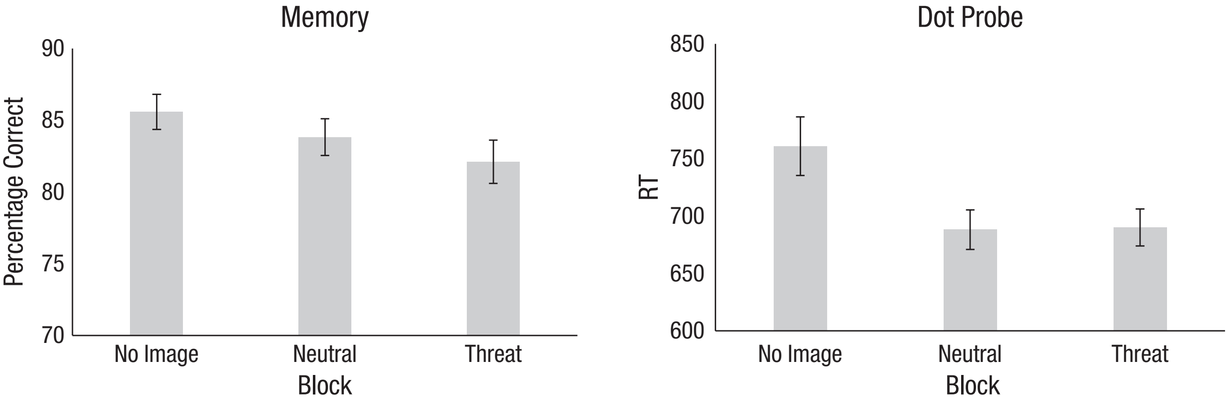

Fig. 2. Results of Experiment 1: percentage of correct responses in the color-memory task (left) and mean reaction time (RT) in the dot-probe task (right) as a function of block type. Error bars show ±1 *SEM*.

ms, and a self-determined short break was given after every 20 trials. During the break, participants saw their percentage of correct answers in the memory task thus far.

A small gray dot (diameter = 0.168°) appeared unpredictably in one quarter of the trials in each block. These dot-probe trials could not be the first trial following a break, and two dot-probe trials could not appear consecutively. The dot appeared randomly at one of the memory-item locations 700 ms after the offset of the memory display. Importantly, this was the time when the intervening event (the display of the distractor image or the disappearance of the fixation cross) was expected (Fig. 1d). Participants were asked to press the space bar as quickly as they could when they detected the dot. Pressing the space bar terminated the trial, and the next trial started after a 200-ms blank intertrial interval.

Design. All participants completed one block of threat trials, one block of neutral trials, and one block of no-image trials. The order of the blocks was counterbalanced across participants. At the beginning of each block, the participants were told whether or not images would be presented in that block. Each block consisted of 120 memory trials and 40 dot-probe trials. Each neutral and threat image was randomly presented four times within its corresponding block. All participants performed at least 20 practice trials in the neutral condition before starting the experiment.

Results

The exclusion criteria were poor memory performance (2 *SD* below the mean) and slow responses in the dot-probe task (2 *SD* above the mean). Three participants were excluded because of slow responses in the dot-probe task.

Memory task. Figure 2 depicts memory performance as a function of block type. A repeated measures ANOVA revealed a main effect of block, $F(2, 114) = 6.0$, $p = .003$, $\eta_p^2 = .095$. Bonferroni-corrected post hoc comparisons showed that this difference was driven by poorer performance in the threat condition relative to the no-image condition, $p = .004$. Performance in the neutral condition did not significantly differ from performance in the other two conditions (*p*s > .19). Reaction time (RT) of correct responses in the memory task did not differ significantly among the conditions, no image = 1,267 ms, neutral = 1,298 ms, threat = 1,344 ms, $F(2, 114) = 2.41$, $p = .09$.

Dot-probe task. Trials more than 2.5 standard deviations above and below each participant's mean of each cell (3.18% of the trials) were removed from the RT analysis. Figure 2 shows mean RT as a function of block type. A repeated measures ANOVA found, once again, a significant effect of block, $F(2, 114) = 13.3$, $p < .001$, $\eta_p^2 = .19$. Replicating and extending the findings of Makovski (2019), our results showed a preparation effect in that responses were faster in the neutral condition than in the no-image condition ($p < .001$, Cohen's $d = 0.543$). More importantly, we found a remarkably similar effect in the threat condition ($p < .001$, Cohen's $d = 0.506$), and indeed there was no RT difference between the threat and the neutral conditions ($p > .86$). The latter finding was confirmed by a Bayesian paired-samples, two-tailed *t*-test analysis that was conducted using JASP (JASP Team, 2018). This analysis revealed moderate support for the null hypothesis of no difference, Bayes factor = 6.9 (e.g., Wagenmakers et al., 2017).

Anxiety-level analysis. Because of technical errors, the STAI data from three participants were not recorded, and these participants were removed from the following analyses.

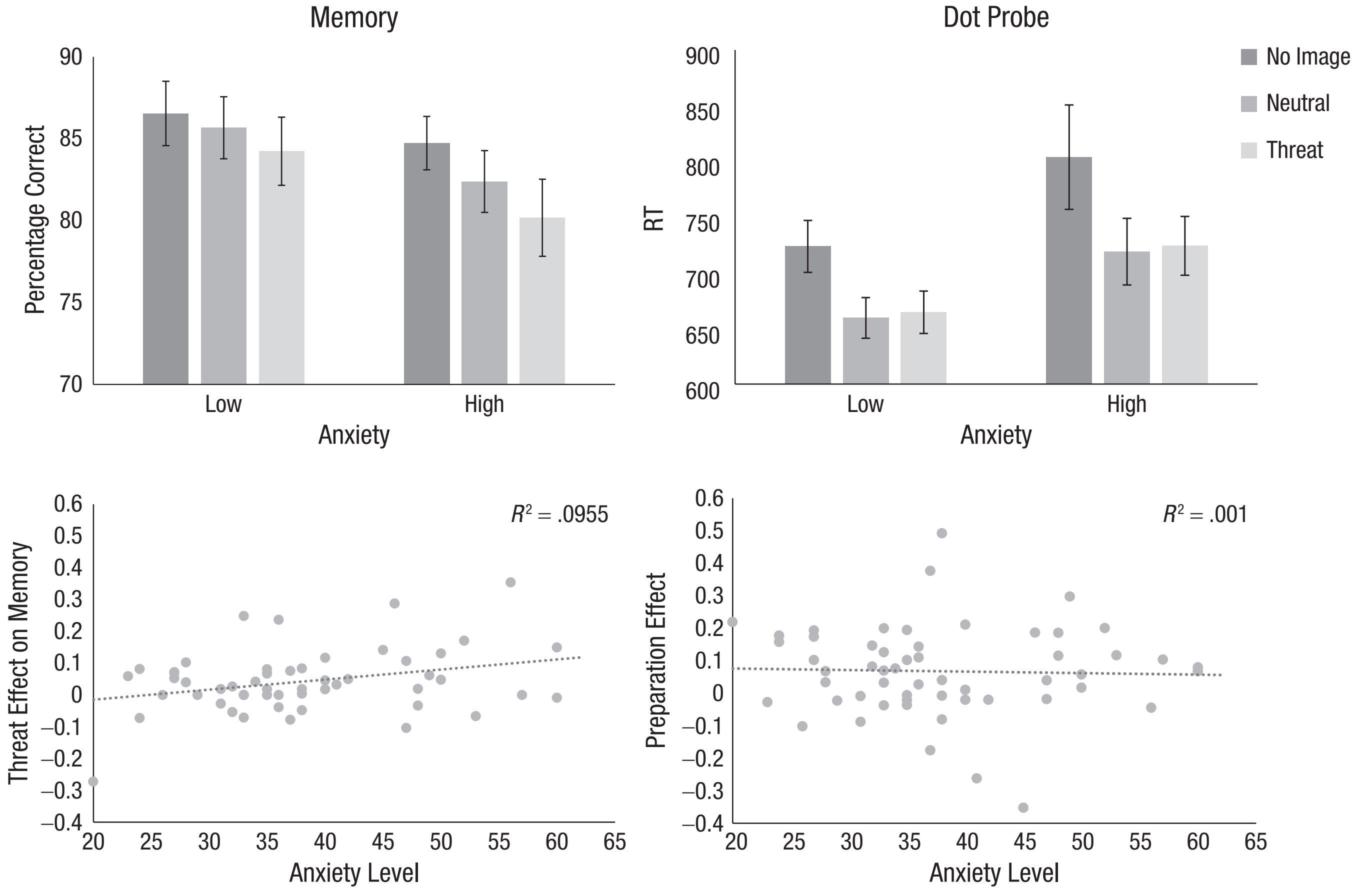

Fig. 3. Effects of anxiety in Experiment 1. The bar graphs show the percentage of correct responses in the color-memory task (left) and mean reaction time (RT) in the dot-probe task (right) as a function of trait-anxiety group and block type. Error bars show ±1 *SEM*. The scatterplots (with best-fitting regression lines) show the relation between anxiety level and the effect of threat in the color-memory task (left) and the preparation effect in the dot-probe task (right). Effects on the *y*-axes of the scatterplots are given in proportions.

First, we divided the participants into high- and low-anxiety groups on the basis of the median split of the trait-anxiety score in the STAI (*Mdn* = 36). Figure 3 (top) shows memory and dot-probe performance as a function of anxiety level and block type. A mixed ANOVA revealed that there was no main effect of anxiety, $F(1, 53) = 1.45$, $p = .233$, and anxiety did not interact with the effect of block type on memory, $F < 1$. Interestingly, however, as can be seen in Figure 3 (top left), there was a trend among the high-anxiety participants to suffer more from the threatening image than the low-anxiety participants did. This was qualified by a positive correlation between the STAI score and the magnitude of interference the participant suffered from the threatening image, calculated as (p(no image) − p(threat))/p(no image), $r(53) = .311$, $p = .02$ (Fig. 3, bottom left). Nevertheless, none of the effects observed in the memory task were found in the dot-probe task. There was no significant effect of anxiety, $F(1, 53) = 3.33$, $p = .074$, and, more importantly, this factor did not interact with the preparation effect, $F < 1$. Furthermore, there was no correlation between anxiety level and the magnitude of the preparation effect, calculated as (RT(no image) − RT(threat))/RT(no image), $r(53) = −.032$, $p = .82$ (Fig. 3, bottom right).

Discussion

The results of Experiment 1 were clear. First, participants were faster to respond to a dot probe when they were expecting an irrelevant distracting image compared with when there was no expectancy of distraction. It is noteworthy that no image was actually presented in the dot-probe trials, and thus the preparation effects were driven merely by the expectation that an image would appear at that moment in time. These results extend Makovski's (2019) findings in that very similar effects emerged in response to a totally irrelevant image and to distracting colors in a color-memory task.

Second and more important, the magnitude of the preparation effect was independent of the image valence, and similar preparation effects were found for the neutral and threatening images. Yet this lack of a difference cannot be the result of a weak emotionality manipulation because the threatening images were processed differently, as indicated by the finding that only these images significantly interfered with the memory task. Furthermore, the cost of the threatening images to the memory task was related to the participant's anxiety level. Nonetheless, neither threat nor anxiety modulated the preparation effect. Together, these findings not only validate our emotionality manipulation but also strongly suggest that the effect of threat and anxiety comes into play after, but not before, the stimuli appear.

Experiment 2

Our goal in Experiment 2 was to further confirm that the findings in Experiment 1 were not the result of a weak manipulation and that the same images can yield strong effects of threat when these are measured after the appearance of the stimuli. Thus, Experiment 2 was largely the same as Experiment 1 except that now the dot probe appeared after the images. If threatening images affected probe detection, in the form of either a slowdown (Algom, Chajut, & Lev, 2004) or a facilitation (Bar-Haim et al., 2007), then one would expect to find different detection latencies in the threat block relative to the neutral block. If, on the other hand, the emotionality manipulation was not strong enough to affect performance, then still no difference should be found between the conditions.

Method

The method was largely the same as the one used in Experiment 1, except that either the memory probe or the dot probe was presented 300, 400, 500, or 600 ms after the intervening image in the neutral and threat conditions or after the reappearance of the cross in the no-image condition. The memory-set size was three for all participants. Because anxiety was not of interest in this experiment, only 30 participants (8 males, mean age = 24.2 years) were tested.

Results

The data from one participant were excluded because of poor performance in the memory task. Another two participants were excluded because of overall slow performance in the dot-probe task. Trials more than 2.5 standard deviations above and below each participant's mean of each cell in the dot-probe task were excluded from the RT analysis (3.25% of the trials).

Memory performance was high and was not affected by block type (all conditions above 90%), $F(2, 52) < 1$. By contrast, RT in the dot-probe task was largely dependent on block type, $F(2, 52) = 31.07$, $p < .001$, $\eta_p^2 = .54$. Bonferroni-corrected post hoc comparisons revealed that RT in the threat condition ($M = 811$ ms, $SE = 27$) was significantly slower than in the neutral condition ($M = 733$ ms, $SE = 23$), which, in turn, was slower than in the no-image condition ($M = 691$, $SE = 22$, all ps < .001).

These results suggest that, first, it was harder to detect the probe when it appeared after an image, perhaps because of forward masking. More importantly for our present purposes, performance slowed considerably after the presentation of threatening images relative to neutral images (Cohen's $d = 0.826$). This finding validates our emotional manipulation and further confirms the hypothesis that threatening stimuli have a strong impact on behavior after they appear.

Experiment 3

One could argue that the threatening images were not negative enough for participants to bother inhibiting them in advance and that therefore a stronger manipulation was still needed. Furthermore, it could be argued that precisely because threat is evolutionarily important, it is crucial for our attention system to allocate more resources to this possibly informative stimulus. By contrast, disgusting stimuli are defined strictly by the fact that they are distracting with no apparent value apart from informing people to avoid them (Knowles, Cox, Armstrong, & Olatunji, 2019). Indeed, although both types of stimuli increase arousal and negative valence, they are likely to be driven by different physiological mechanisms and to produce different behavioral outcomes (Carretié, Ruiz-Padial, López-Martin, & Albert, 2011; Chapman, Johannes, Poppenk, Moscovitch, & Anderson, 2013; van Hooff, Devue, Vieweg, & Theeuwes, 2013; Xu et al., 2016).[2] Hence, to strengthen the emotionality manipulation and to further generalize our results to different types of stimuli, we compared disgusting images with positive, joyful images in this experiment.

Method

The experiment was similar to Experiment 1 except that instead of the neutral and threat images, two sets of 15 joyful and disgusting images were used. Consequently, each image was presented eight times within each block. The validity and intensity of the sets were confirmed in a previous study (Markovitch, Netzer, & Tamir, 2017).[3] To further strengthen the emotionality manipulation, we presented the intervening images for 450 ms. The memory-set size was three and, in all other respects, the method was identical to that of Experiment 1. Fifty-nine participants (20 males, mean age = 25.0 years) completed this experiment.

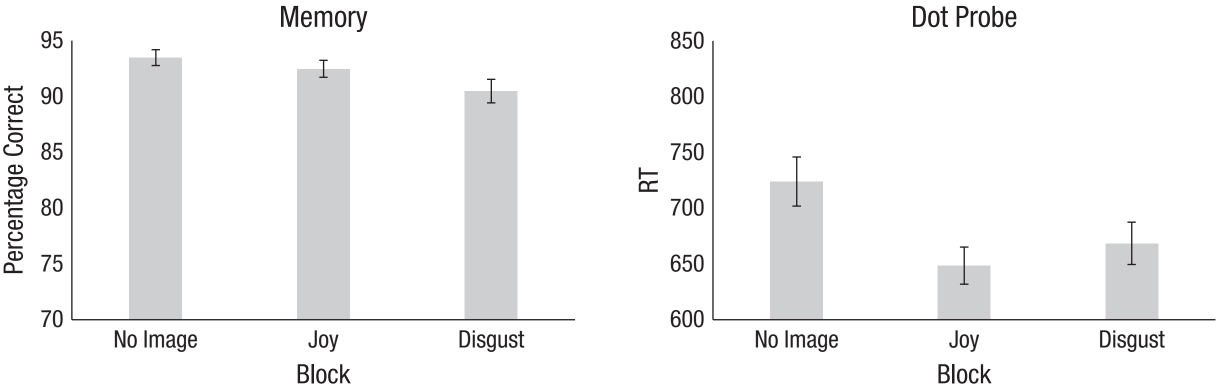

Fig. 4. Results of Experiment 3: percentage of correct responses in the color-memory task (left) and mean reaction time (RT) in the dot-probe task (right) as a function of block type. Error bars show ±1 *SEM*.

Results

The data from four participants were excluded because of poor performance in the memory task. Another two participants were excluded because of overall slow performance in the dot-probe task. Figure 4 depicts the memory and dot-probe results as a function of block type.

Memory task. As in Experiment 1, there was a main effect of block, $F(2, 104) = 8.8$, $p < .001$, $\eta_p^2 = .145$. Bonferroni-corrected post hoc comparisons confirmed that disgusting images impaired performance relative to both the no-image condition ($p = .002$) and the joy condition ($p = .025$). There was no difference between the joy and no-image conditions ($p = .28$). Block type did not affect the RT of the correct responses (no image: $M = 1{,}305$ ms, joy: $M = 1{,}293$ ms, disgust: $M = 1{,}304$ ms; $F < 1$).

Dot-probe task. Trials more than 2.5 standard deviations above and below each participant's mean of each cell (2.79% of the trials) were excluded from the RT analysis. As in Experiment 1, there was a main effect of block, $F(2, 104) = 17.2$, $p < .001$, $\eta_p^2 = .25$. Bonferroni-corrected post hoc comparisons revealed preparation effects for both the joyful and disgusting stimuli: Probe detection in these blocks was faster than in the no-image condition (disgust: $p = .002$, Cohen's $d = 0.494$; joy: $p < .001$, Cohen's $d = 0.726$). There was no significant difference between RTs in the joy and disgust conditions ($p = .12$); however, the Bayes factor of the paired-samples t test was 1.11, indicating inconclusive evidence. Nevertheless, a one-way ANOVA comparing the magnitude of the preparation effect as a percentage across the four conditions tested in Experiments 1 and 3 was nonsignificant ($F < 1$): neutral ($M = 7.8\%$, $SE = 1.9$), threat ($M = 6.82\%$, $SE = 2.0$), joy ($M = 9.6\%$, $SE = 1.6$), and disgust ($M = 5.8\%$, $SE = 1.9$). The accumulated results clearly indicate that a preparation effect took place in all blocks in which a distracting image was expected, and the magnitude of the effect was largely independent of the stimulus valence.

Anxiety-level analysis. Because of technical errors, the STAI data from one participant were not recorded. As in Experiment 1, we initially divided the participants into high- and low-anxiety groups on the basis of the median split of the trait-anxiety score (*Mdn* = 37; Fig. 5, top). There was no significant effect of anxiety in either the memory task, $F(1, 50) = 2.87$, $p = .096$, or the dot-probe task ($F < 1$). This factor also did not interact with block type in either task (ps > .32). We also replicated our previous findings of a positive correlation between trait anxiety and the interference from the disgusting image in the memory task, $(p(\text{no image}) - p(\text{disgust}))/p(\text{no image})$, $r(50) = .291$, $p = .037$. Yet once again, no such correlation was found in the dot-probe task, $r(50) = -.12$, $p = .40$ (Fig. 5, bottom). These findings suggest that both image emotionality and the individual's anxiety level are related to behavioral performance after the image is presented. However, these factors have no impact on attention before the image is presented, and the preparation effect does not seem to be related to the individual's anxiety level or to the emotionality of the image.

General Discussion

The present study showed that although threatening and disgusting stimuli clearly impaired performance after they appeared (Experiments 1–3), participants did not inhibit them in advance. Rather, they were more alert when they were expecting any stimulus to appear: negative, neutral, or joyful. Furthermore, even though the interfering effects of threat and disgust were modulated by anxiety, these factors did not impact the preparation effect. Hence, these results imply that the preparation effect is a rigid mechanism that depends neither on the emotional valence of the stimulus nor on the anxiety level of the observer.

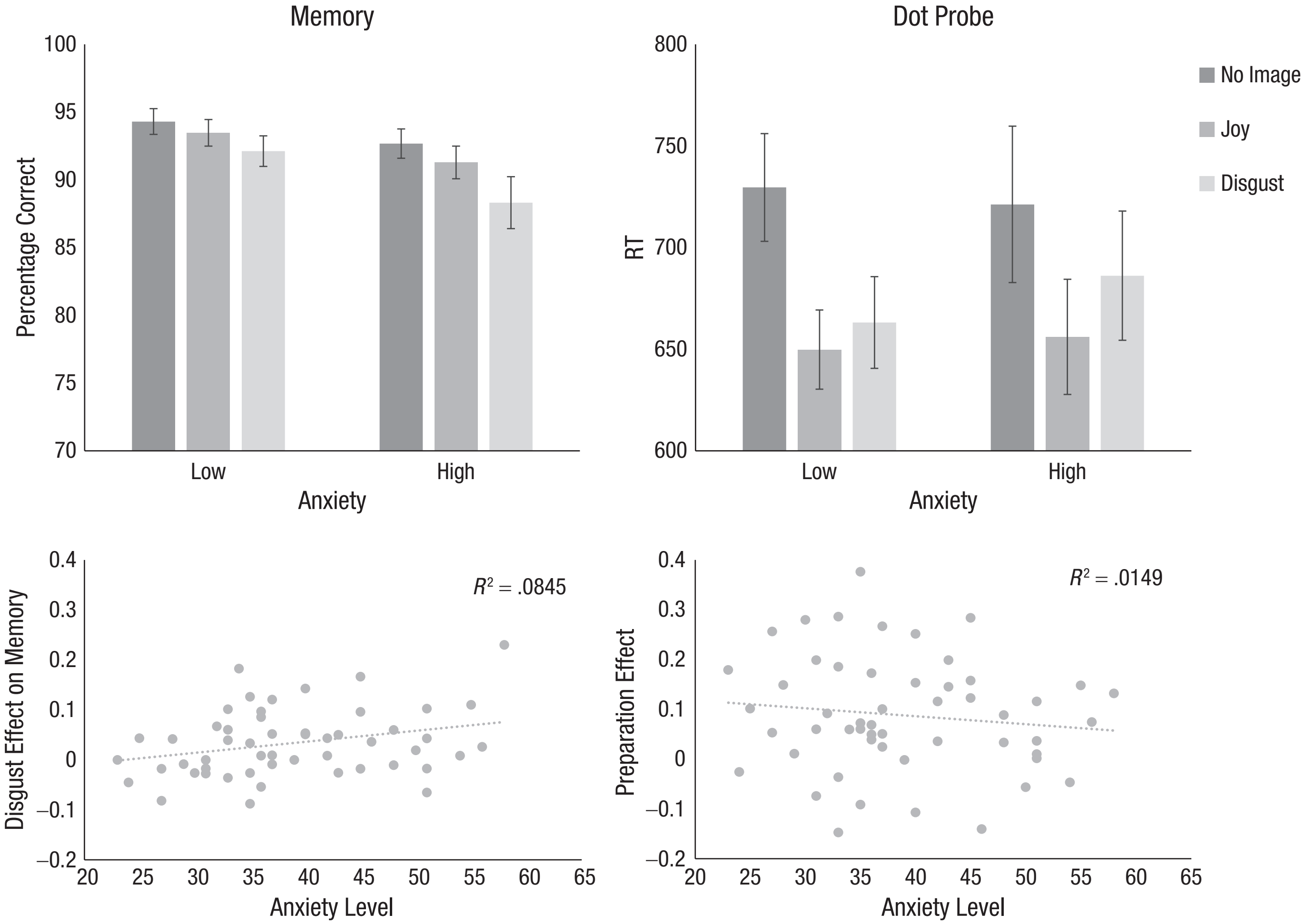

Fig. 5. Effects of anxiety in Experiment 3. The bar graphs show the percentage of correct responses in the color-memory task (left) and mean reaction time (RT) in the dot-probe task (right) as a function of trait-anxiety group and block type. Error bars show ±1 *SEM*. The scatterplots (with best-fitting regression lines) show the relation between anxiety level and the effect of disgust in the color-memory task (left) and the preparation effect in the dot-probe task (right). Effects on the *y*-axes of the scatterplots are given in proportions.

These results further extend the finding that observers prepare for distractors just as they prepare for informative stimuli (Makovski, 2019). This generality of the preparation effect supports a mandatory process-all mechanism (Tsal & Makovski, 2006) in which the visual system allocates more attentional resources prior to any upcoming stimulus regardless of its valence or informative value. This further supports the possibility that the preparation effect is actually an evolutionary-adaptive mechanism that facilitates the suppression of irrelevant stimuli after they appear. Importantly, the visual system seems to prefer suppressing distracting stimuli after first viewing them as opposed to shutting down attention beforehand (Chang, Cunningham, & Egeth, 2019; de Vries, Savran, van Driel, & Olivers, 2019).

The present data also imply that the effects of emotional stimuli largely occur only after they appear. Consistent with previous findings, the results of all three experiments revealed considerable effects of emotion on behavior when these were measured after the appearance of the stimulus. Furthermore, in line with the notion that the link between emotion and attention is related to anxiety, Experiments 1 and 3 found that the effect of valence on performance was modulated by anxiety. Nevertheless, no such modulation was found in the preparation effect. This is consistent with findings of a recent study showing that top-down expectations do not modulate the interference from emotional distractors. Only after sufficient experience with the negative stimuli can the interference effect be somewhat reduced (Schmidts, Foerster, Kleinsorge, & Kunde, 2020; see also Cunningham & Egeth, 2016, on the reduction of the attentional white-bear effect over time). Notably, however, the extent to which top-down modulation affects emotional distraction is still debated; some researchers have found that increasing frequency or reward reduces emotional distraction (e.g., Grimshaw, Kranz, Carmel, Moody, & Devue, 2018; Walsh, Carmel, & Grimshaw, 2019), whereas others have not (Zhao & Most, 2019). Thus, it remains to be determined how flexible the mechanisms for preparing for and processing emotional distractors are.

Naturally, it still needs to be shown whether these effects also apply to clinical populations. It is possible that the effect behaves differently for more extreme stimuli or populations (Bar-Haim et al., 2007; but see Aue, Chauvigné, Bristle, Okon-Singer, & Guex, 2016). Still, the present results clearly indicate that top-down knowledge about any upcoming stimulus, regardless of emotionality, increases rather than decreases alertness and that the effects of emotional stimuli on behavior largely occur only after the stimuli are presented.

Transparency

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Author Contributions

T. Makovski developed the study concept. Both authors contributed to the study design. T. Makovski programmed the experiments and analyzed the data. T. Makovski drafted the manuscript, and E. Chajut provided critical revisions. Both authors approved the final manuscript for submission.

Declaration of Conflicting Interests

The author(s) declared that there were no conflicts of interest with respect to the authorship or the publication of this article.

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Open Practices

Data and materials for the experiments have not been made publicly available, and the design and analysis plans were not preregistered.

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Notes

1. Each participant took part in only one of the experiments.
2. We thank Simone Moran for raising this idea.
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